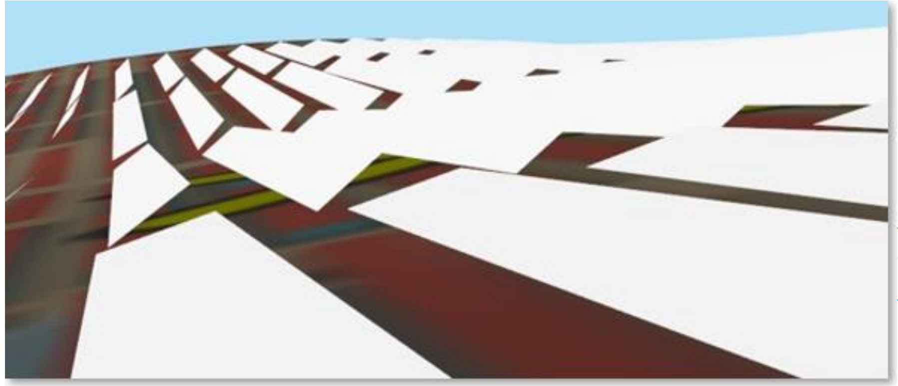
WHEN TRUST MATTERS



# Tackling the terrain: Custom tracking algorithms in solar PV plants on complex terrain

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Jason Alderman (Nevados Engineering)

2024 PVPMC, Salt Lake City, USA
9 May 2024

# PV, DNV & SolarFarmer

DNV

- Independent engineers; assurance & risk
- Foundation, with Norwegian HQ
- 5% R&D re-investment
- Strategy goals: Decarbonisation & Digitalisation
- 250 PV Engineers & Scientists

SolarFarmer

- Software for bankable yield estimates
- Industrial & utility scale projects
- 3D: complex terrain & shading
- Easy to use
- Enables scalability

# Irregular terrain – the reality of PV plants

- Flat terrain (without earthworks) is scarce:
  - Environmental cost, community acceptance, permitting.
- Irregular terrain causes electrical mismatch losses due to row-to-row (mutual) shading.
- Several manufacturers have developed terrain-following trackers and new tracking algorithms:
  - Faster construction times and reduce project costs.

**Aim of this work**

- Investigate how terrain affects energy yield assessments.
- Illustrate how custom rotation schedules can be used to compensate terrain losses.
- Present results and learnings from PV projects on complex terrain:
  - Industry collaboration between DNV (independent engineer) and Nevados (tracker manufacturer)
  - 2 case studies (1 commercial & 1 fictitious project)

# Case study A

Commercial project
in New York

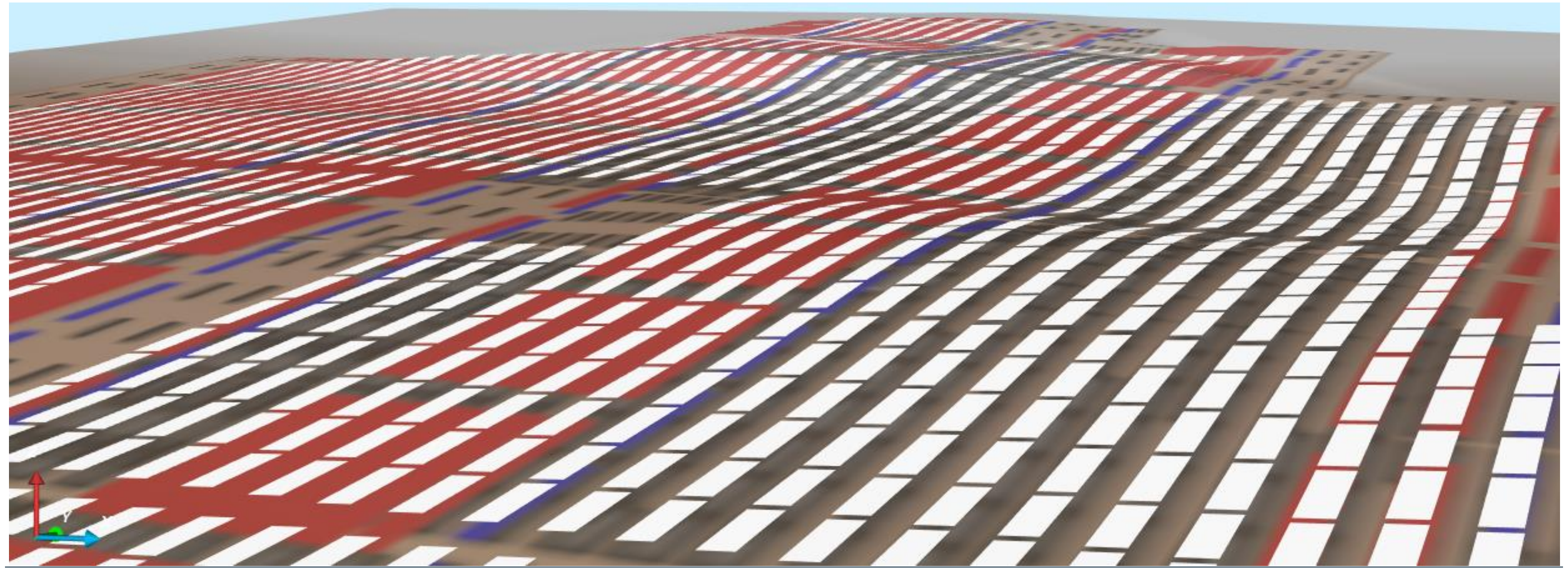
7.2 MWp

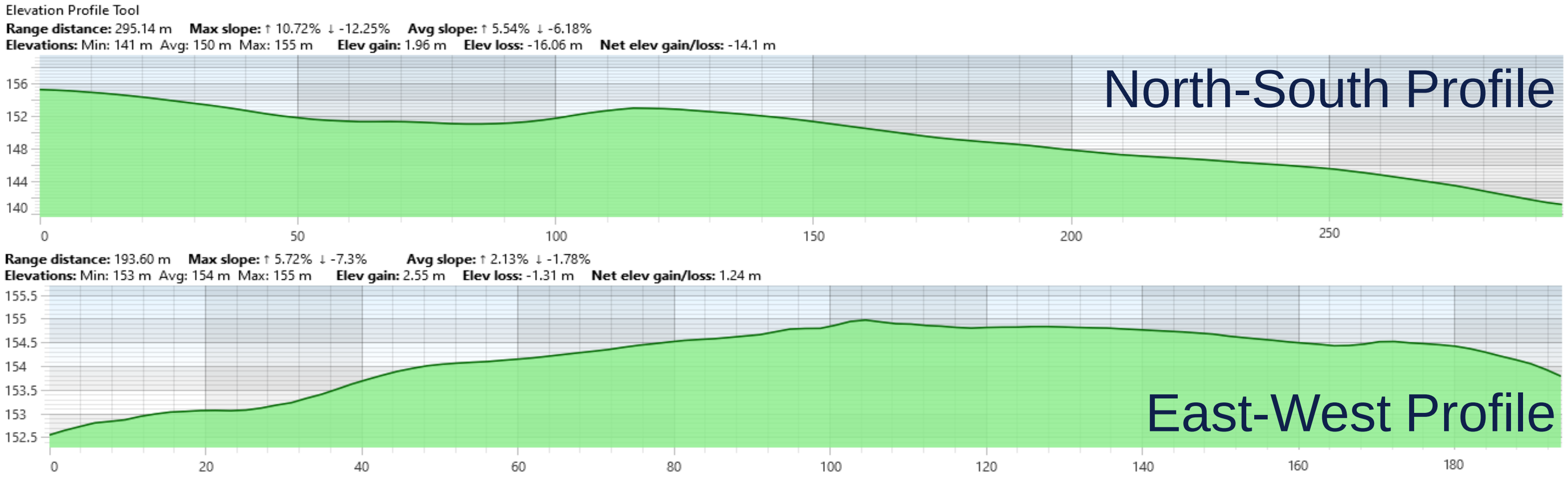
Overall (average) terrain

*Axis tilt: 2.9 deg*

*Side slope: 0.3 deg*

*SolarFarmer 3D render of the site*





# Case study B

## Fictitious project in Nevada

14.6 MWp (DC/AC ratio 1.17)

10 inverters

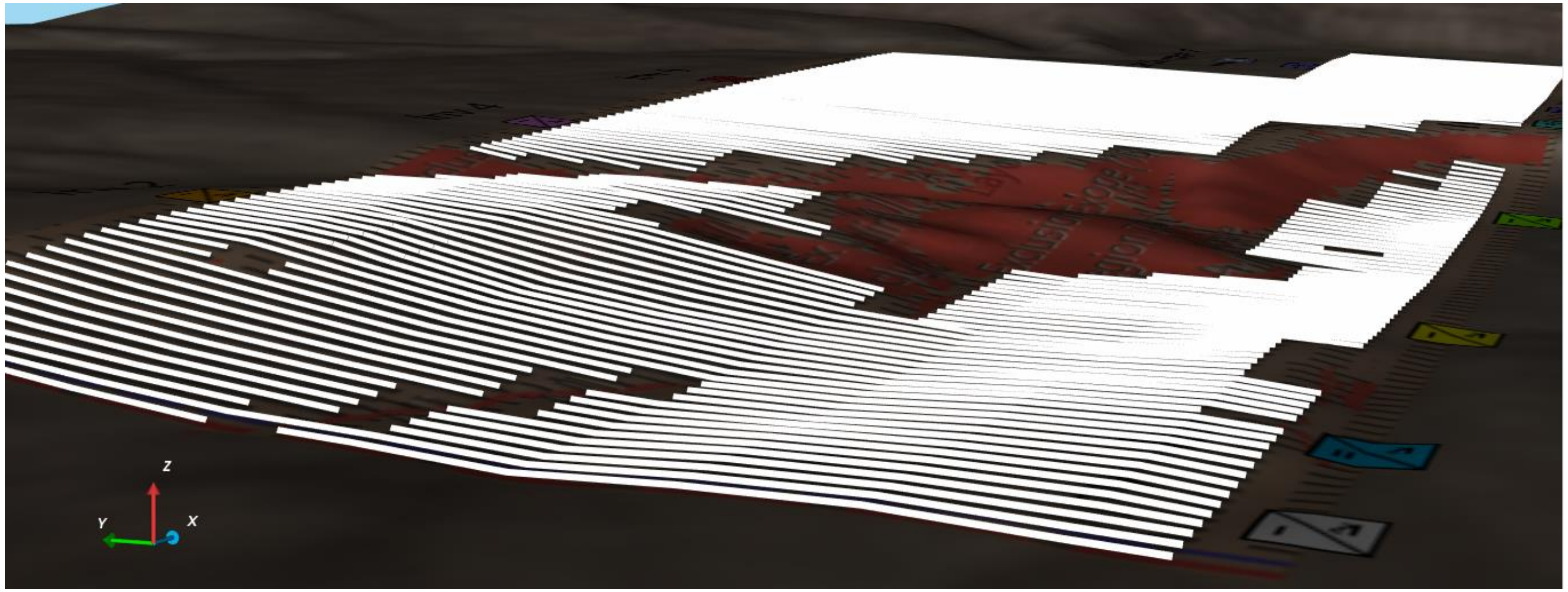
823 trackers (1 & 2 string length)

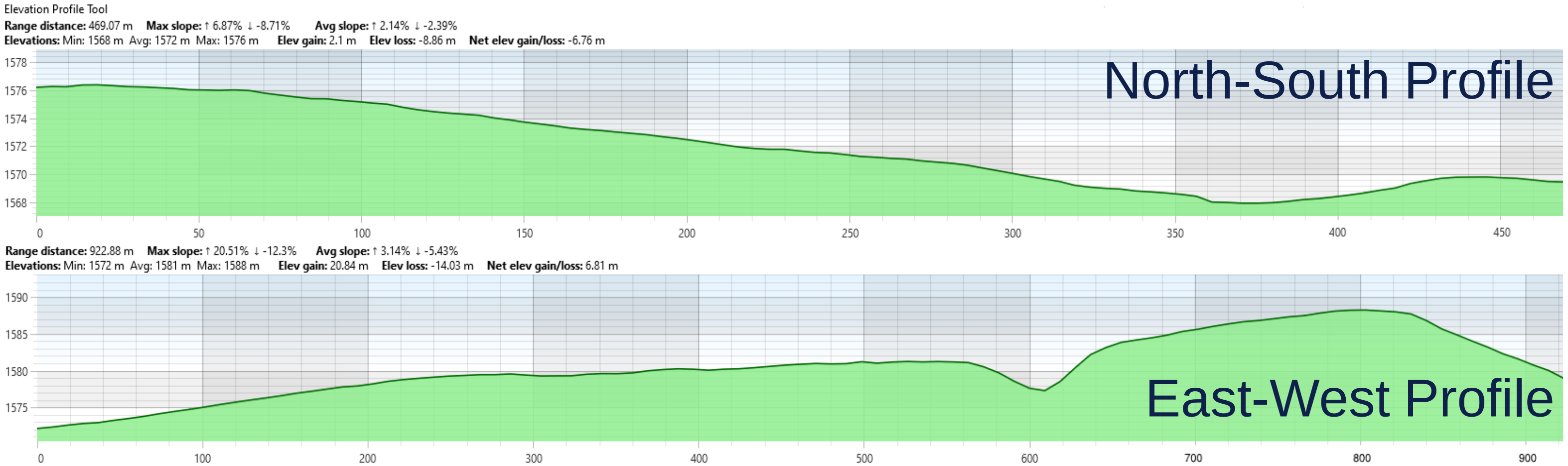
## Overall (average) terrain

*Axis tilt: 2.7 deg*

*Side slope: 0.1 deg*

*SolarFarmer 3D render of the site*



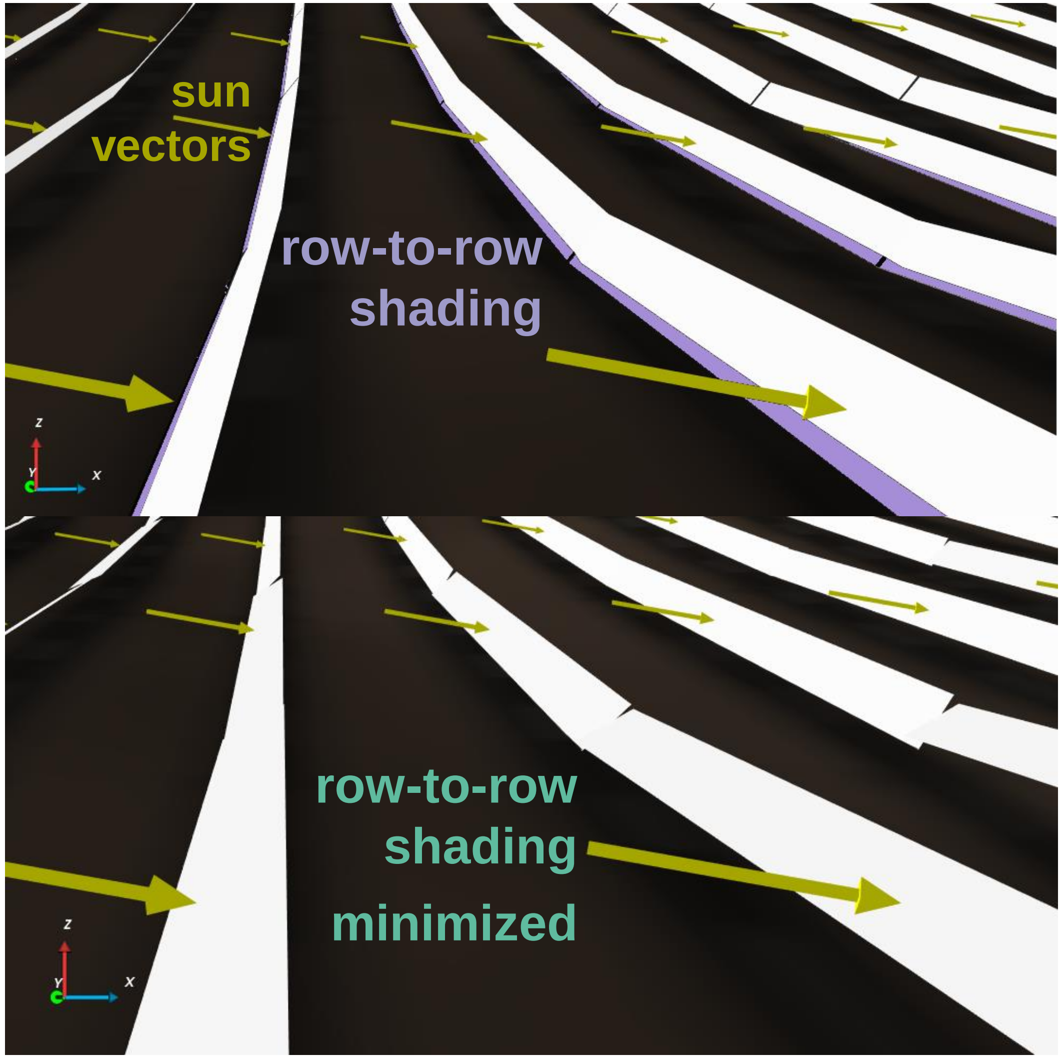



# Methodology – SolarFarmer 3D modeling

- SolarFarmer’s 3D hemicube model
- 5-minute timeseries for 1 year
- Comparison of several energy assessments:

| Terrain | Tracking algorithm |
|---|---|
| 2D Horizontal | Standard backtracking |
| 2D average slope | |
| High-resolution 3D terrain | Standard backtracking |
| | Planar slope-aware backtracking[1] |
| | Custom rotation schedules (Nevados TRACE[2]) |

*SolarFarmer 3D view of row-to-row shading: standard backtracking (top) vs custom rotations (bottom)*




[1]K. Anderson and M. Mikofski (2020), NREL/TP-5K00-76626
[2]TRACE: Tracker Rotation Angle Calculation Engine

# Effects in yield and modeling losses (case study A)

| Model | 2D horizontal | 2D average slope | 3D high-resolution terrain | | |
|---|---|---|---|---|---|
| Backtracking | Standard | Standard with N/S slope | Standard | Planar N/S+E/W slope | Nevados TRACE |
| Plane of array (POA) gain [%] | 23.1 | 25.5 | 25.4 | 25.4 | 23.6 |
| Near shading effect [%] | -2.9 | -2.6 | -2.6 | -2.6 | -2.1 |
| Electrical mismatch effect [%] | 0 | 0 | -2.7 | -2.7 | -0.1 |
| **Energy assessment summary** | | | | | |
| Year 1 - Yield Factor [kWh/kWp] | 1424.6 | 1446.6 | 1408.6 | 1408.7 | 1429.1 |
| Year 1 - Normalized Generation (reference 2D horizontal) | - | +1.54 | -1.13 | -1.12 | +0.31 |

3D modeling illustrates the electrical mismatch due to the terrain

Custom rotation schedules can reduce electrical mismatch losses to levels of flat sites, leading to higher energy yield

# Effects in yield and modeling losses (case study B)

| Model | 2D horizontal | 2D average slope | 3D high-resolution terrain | | |
|---|---|---|---|---|---|
| Backtracking | Standard | Standard with N/S slope | Standard | Planar N/S+E/W slope | Nevados TRACE |
| POA gain [%] | 41.6 | 43.8 | 43.7 | 43.7 | 42.2 |
| Near shading effect [%] | -1.6 | -1.5 | -1.7 | -1.7 | -1.1 |
| Electrical mismatch effect [%] | 0 | 0 | -3.0 | -3.0 | -0.5 |
| **Energy assessment summary** | | | | | |
| Year 1 - Yield Factor [kWh/kWp] | 2168.4 | 2201.6 | 2129.4 | 2129.2 | 2175.2 |
| Year 1 - Normalized Generation (reference 2D horizontal) | - | +1.53 | -1.08 | -1.09 | +0.73 |

Near-shading losses can also be reduced with more conservative backtracking (larger unobstructed sky view)

Custom rotation schedules leading to 0.7% gain in generation

# Conclusions

- 3D energy calculations capture terrain losses
  - → A way to move away from constant loss factors
- Custom tracking rotations can improve energy yield significantly
  - → Modeling examples with SolarFarmer 3D using Nevados TRACE rotations
  - → Losses are recovered from the terrain:
    - near-shading and electrical mismatch losses can be minimized.
    - higher yield factors and generation compared to flat equivalent sites.
    - additional energy gains by changing tracker algorithm software.

# Future work

- More validation … continuously
  - Collaborations?
- More compute optimizations (faster and scalable calculations)

# See more at …

DNV SolarFarmer's table during the Industry Modeling Software Office Hours *(Parallel Session C)*

Today @ 13:25h

DNV SolarFarmer public training May 30th and 31st (8-11AM US Pacific)
https://store.veracity.com/solarfarmer-training

More on trackers on terrain in SolarFarmer at IEEE PVSC Seattle, June 9-14

→ *Energy yield modeling of single-axis tracking PV systems on irregular terrain*

# Thank you!

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NEVADOS
ALL TERRAIN TRACKER

DNV